

IRRIGATION ON THE PRAIRIES

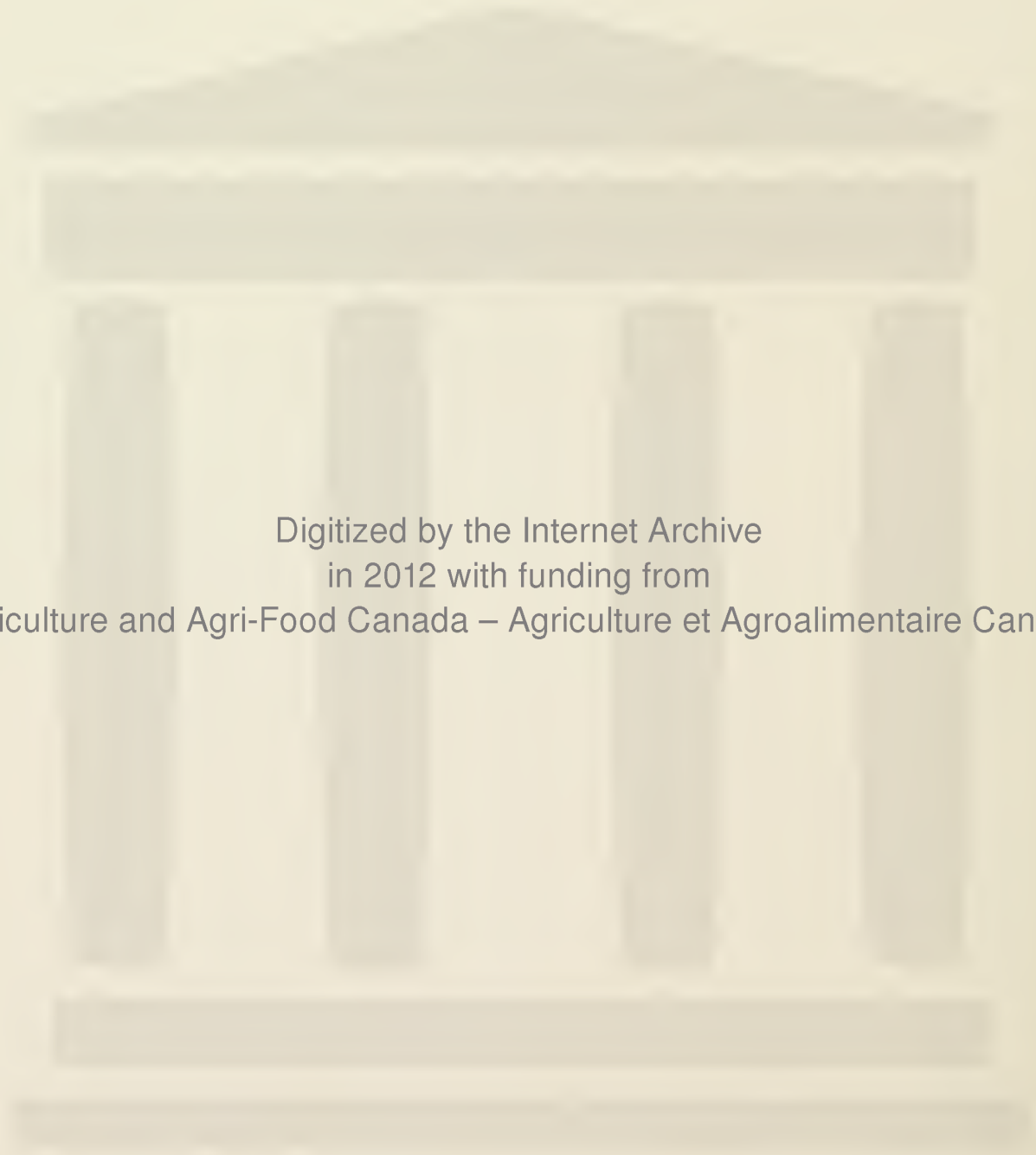
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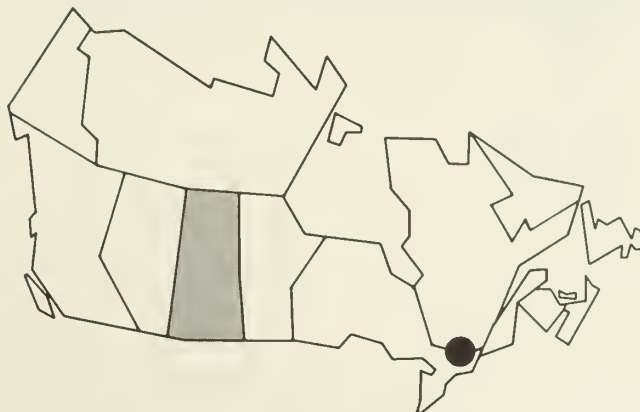


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IRRIGATION ON THE PRAIRIES

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Irrigation is the practice of supplementing natural precipitation by the artificial application of water in an endeavor to maximize crop production. Considerable planning is required because several factors must be considered. These include water supply, topography and soil characteristics as they relate to the choice of crop, cultural practices, and method of irrigation. In addition, certain legal arrangements have to be made to obtain the right to use the water.

Irrigation systems may be very simple or immensely complex. Little planning is required if the system is to consist of leading spring runoff over 100 acres of low-lying hay land. If, on the other hand, the development is a large multipurpose system consisting of large reservoirs and extensive distribution systems, planning is very complex.

The cost of irrigation development may vary from less than \$50 to more than \$500 per acre, depending on the complexity and sophistication of the scheme. Economic considerations alone are enough to demand that the irrigation farmer irrigate as well and efficiently as possible. More important, though, is the realization that good irrigation can augment and expand the total agricultural economic capability of an area.

PLANNING

There are three basic ways of applying water to the soil:

- Surface irrigation — Water is applied by complete flooding, as in border irrigation; by partial flooding, as in the furrow method; or by applying it continuously at a very low rate as in the trickle method.

- Sprinkler irrigation — Water is supplied under pressure to rotating sprinklers that distribute the water from overhead. The high cost of labor for moving pipes by hand has accelerated the development of mechanical-move systems, such as the tractor end-tow side-roll and center-pivot.

- Subirrigation — Water is applied beneath the soil surface, wetting the surface very little, if at all.

Surface and sprinkler methods are the most common, and the choice depends mainly on water supply, topography and soil type.

Water Supply

Water Quantity

The type of water supply can have a bearing on the selection of method of irrigation. A large reservoir from which large flow rates are available by gravity is well suited to a surface method of irrigation. So also is a

stream with a fluctuating flow. On the other hand, a well with a continuous low flow will probably irrigate more land at a higher efficiency if applied through a sprinkler irrigation system. A large-capacity well located in the center of a quarter section would be ideally suited to the center-pivot self-propelled system.

The quantity of water required can be considered on the basis of a volume or a flow. Using an average seasonal irrigation requirement of 18 inches (Table 1) and considering an area of 100 acres, the net volume required would be 150 acre-feet (1.5 feet on 100 acres = 150 acre-feet). Assuming an irrigation efficiency of 70%, the amount required increases to 214 acre-feet to which has to be added evaporation losses from the reservoir in the case of a surface supply. Using an average evaporation loss of 1.5 feet and assuming the reservoir covers 30 acres, an additional 45 acre-feet of water is required, making a total of 259 acre-feet. An average figure, therefore, of 2.5 acre-feet of water for each acre to be irrigated is generally used in the planning stages.

TABLE 1. WATER USE BY CROPS

Crop	Water use, in.			
	Irrigation requirement		Consumptive use	
	S. Alta.	S. Sask.	S. Alta.	S. Sask.
Alfalfa	16	20	26	26
Alfalfa + Bromegrass		18		24
Pasture	12		24	
Sugar beets	13	14	22	24
Potatoes	14	15	20	21
Soft wheat	10		19	
Hard wheat	10	13	18	21
Oats	9		16	
Barley	10	13	16	19
Flax	5		15	
Corn	8		15	
Tomatoes	7		14	
Peas	8	10	13	19

Consumptive use: Rainfall + irrigation + soil moisture deficit.
 Southern Alberta: 11 years' data (1950-61); Sonmor (11).
 Southern Saskatchewan: 5 years' data; Pohjakas et al. (9).

If the water supply is in the form of a well, there will be no loss from evaporation and the supply is usually considered in terms of a flow in gallons per minute (U.S. measure used in text). The flow required can be calculated from the formula:

$$\text{flow} = \frac{27,154 \times I \times A}{H \times D \times 60}$$

where 27,154 = U.S. gallons in 1 acre-inch

I = inches of water to be applied (3.5 inches in 2 weeks)

A = acres to be irrigated (100 acres)
H = hours of operation per day (22 hours)
D = days required to irrigate once over (12)

$$\text{flow} = \frac{27,154 \times 3.5 \times 100}{22 \times 12 \times 60} = 600 \text{ gpm (U.S.) or}$$

860 gpm at an efficiency of 70% (8.6 gpm per acre).

Water Quality

The water quality on the prairies is usually very good because the most common supply is surface water from snowmelt. However, it is still wise to check by sending a sample to the Soils Testing Laboratory at your nearest university.

Topography

Topography is the most obvious physical feature and probably controls irrigation development as much as the water supply. The degree of roughness may be such that it would be uneconomical to prepare the area for surface irrigation. If the land is relatively level in one direction but too steep for border dykes, it may be necessary to use furrows or sprinklers.

A basic requirement in these considerations is an engineering survey of the area. The resultant topographic drawing, which shows the physical features of the land surface by means of contour lines, is used in most steps in the development of a project; selection of the method of irrigation, calculation of earthwork required for land grading, layout of pipes and ditches, determination of size of most suitable water stream and the amount of power required for the pump. The drawing will be used mostly for the land grading operation which is a major aspect of irrigation development, particularly when the water is applied by one of the surface methods.

Field shape and presence of obstructions such as fence and pole lines may also pose restrictions, particularly for sprinkler development. Small irregularly shaped fields complicate irrigation and farming operations, but surface methods and hand-move sprinklers are more flexible than mechanical-move sprinklers. The side-roll is practically limited to regularly sloped fields $1/4$ mile wide and free of obstruction such as power or telephone lines. The center-pivot is limited to a quarter section of land free of obstruction.

Soil

A soil may be classified as suitable, unsuitable or marginal for irrigation. The texture of the soil influences the method or type of irrigation to be used. For

example, sprinkler irrigation is better suited to coarse-textured soils, such as sandy loams, because the faster infiltration rate allows the use of higher-volume sprinklers with a subsequent reduction of equipment. In addition, a high infiltration rate is detrimental to development of surface methods because the length of run that can be allowed is relatively short, causing an increase in labor requirements and a decrease in field size. It is just the opposite on fine-textured soils: the low infiltration rate allows longer runs desirable for the surface methods, but limits the size of sprinklers and this increases the cost of sprinkling because more equipment is required than for coarse-textured soils.

Figure 1 depicts the methods most suitable for different land slopes and soil textures. The methods are somewhat versatile and, depending to a certain extent on capital costs, are not necessarily restricted to locations shown on the chart.

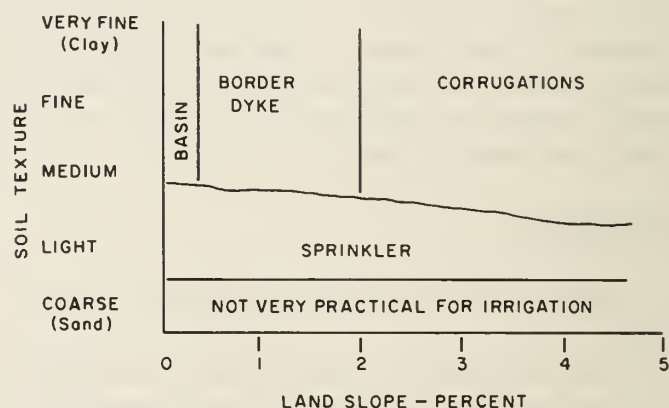


Figure 1. Topography — irrigation relationship in general.

Assistance Available

The assessment of water, topography and soil requires technical assistance which is available from the Canada Department of Agriculture research stations, PFRA of the Department of Regional Economic Expansion, universities and provincial departments of agriculture. Additional engineering and financial assistance is available on application, for the development of both individual and group projects. The objectives of the assistance policies are to advance soil and water conservation for agricultural purposes and the beneficial use of both water and land resources. The branches to contact for engineering and financial assistance are: federal government — PFRA of the Department of Regional Economic Expansion; Manitoba — Agricultural Engineering Division of the Extension Service, Manitoba Department of Agriculture; Saskatchewan — Conservation and Land Improvement Branch, Saskatchewan Department of Agriculture; and Alberta — Water Re-

sources Division, Alberta Department of Environment and Extension Service, Alberta Department of Agriculture. The respective Provincial Water Rights Office must also be contacted for authorization to use the water.

IRRIGATION METHODS

Surface Irrigation

Surface methods of irrigation include spring flood, contour ditch, border ditch, border dyke, furrow, corrugation and basin. The most common of these is the border dyke for intensive (full season) irrigation.

Spring Flood

Spring flood, as its name implies, consists of controlling the spring runoff by impounding the water on

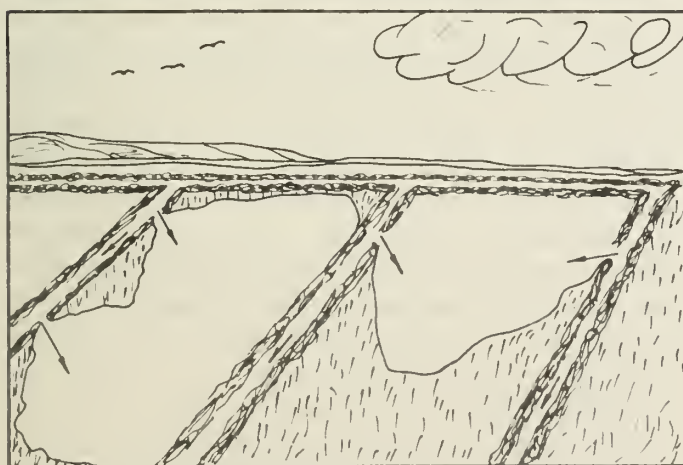
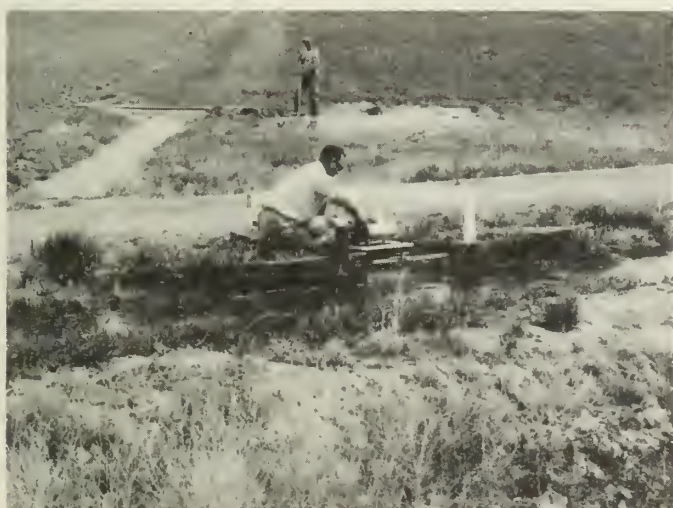


Figure 2. Border ditch method of irrigation.

the land until the soil reservoir is full and then releasing it. This method is usually used to increase production on low-lying hay lands and in most years there is only the one application in the spring. The system may consist

simply of a dyke with a control gate in it across the lower end of the flat which impounds the water and back floods the low land. More sophisticated systems control and regulate the flow of water through a series of dykes.

The cost is relatively low and increases in yield need not be dramatic to meet the added expense. Yield data from several spring flood systems studies at Swift Current* showed a wide variation in yield from year to year depending on the season. However, in some years yields were double or even triple those on dry land.

Contour Ditch

This method consists of free flooding from ditches running approximately on a contour and spaced 75 to 300 feet apart. As labor is high and efficiency low for this method, it should be used only until land grading can be completed for a more efficient method.

Border Ditch and Border Dyke

Border ditch — In this method parallel ditches are run down the field 75 to 125 feet apart and the strip between is irrigated by turning water into the strip at any number of ditch locations (Figure 2). Since the water is applied at several downfield locations, slope can be overcome by turning water onto the strip at the high spots. On the other hand, labor is relatively high, the ditches pose a weed problem and are inconvenient for farming operations. Border ditches are very effective on level land because at the end of the irrigation the ditches can be used to drain off excess water. It is recommended that this method be considered only as a temporary measure during land development processes.

Border dyke — This method consists of parallel dykes 4 to 6 inches high from 30 to 65 feet apart running down the field slope (Figure 3). Water is turned into the strip at the top end and, spreading between the dykes, runs down the full length of the strip.

Border dykes can be used on most crops and are especially suited to forage crops. This method requires the greatest degree of land grading, but it can be most efficient, with very low labor costs. It is usually limited to land having a down-field slope less than 2%, although it has been used successfully on steeper lands.

The length of run depends on the type of soil. However, the length can be somewhat compensated for by the rate the water is turned into the strip. The flow is between the minimum required to spread the water

*Unpublished annual reports, Research Station, Swift Current, Saskatchewan.

adequately across the strip and the maximum possible without causing erosion (nonerosive flow). Lengths of run can vary from 500 to 2000 feet but in general are from 800 to 1300 feet. Lengths of run less than 500 feet, due either to changes in field slopes or sandy soils, increase labor and tend to cut up the fields to a point where the advantages of this method are dissipated.

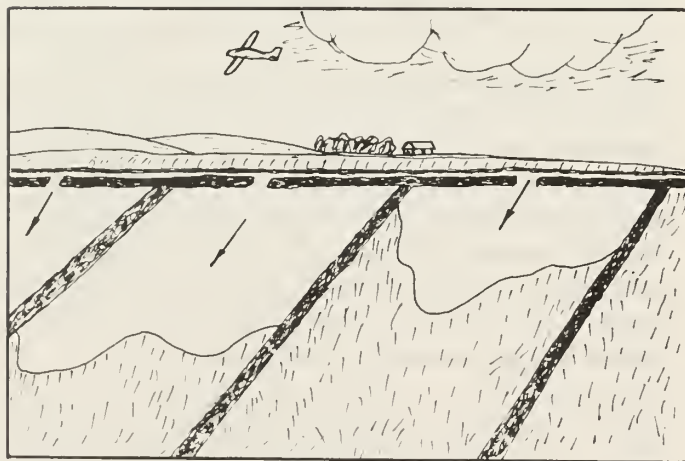


Figure 3. Border dyke method of irrigation.

Comparison of border dyke and border ditch — The two methods were compared at Swift Current (6) on a fine-textured clay soil with a down-field slope of 0.16% and 1680-foot-long strips. Three widths of border ditch strips (75, 100 and 120 feet) were compared with 65-foot-wide border dyke strips. This study showed that a strip length of 1680 feet was not too long, and that the water was as uniformly and efficiently applied on the wide border ditch strip (125 feet) as on the narrow strip (75 feet). An analysis of the water application efficiency and coefficient of uniformity of water application data indicated no significant difference between the two methods. The average water application efficiency was

70.5%, and the average coefficient of uniformity was 70.9%.

The effect of size of irrigation stream and soil moisture at the time of irrigation on the efficiency and uniformity of water application was also analyzed. These analyses showed that both efficiency and uniformity improved the drier the soil was at the time of irrigation. Water application efficiency was not affected by a change in the size of irrigation stream used; but the water was applied more uniformly on border ditch irrigation when larger streams were used. The study showed that when irrigating by border ditch a small stream of water should be used when a light application is desired. This is opposite to the common concept that a light application is achieved by irrigating quickly with a large stream.

Although the irrigation efficiency of the two methods was similar, it must be pointed out that the land was prepared according to border dyke standards. The comparable efficiency was not obtained at the lower standard of land preparation that it was suggested the border ditch method could handle. Furthermore, labor requirements for irrigation and ditch maintenance are higher when border ditches are used, and farming operations are more inconvenient because of the separate strips. For these several reasons the use of border dykes is strongly recommended for the irrigation of close-growing crops on the prairies.

Furrow and Corrugation

Furrow and corrugation methods of irrigation utilize small channels running down field and usually spaced 3 feet apart (Figure 4). Furrows are used in row crops with the water confined in each channel. Furrows are generally larger than corrugations because the crop may be hilled or row cultivated. Corrugations are used in close-growing crops. Where slopes are not more than 1% and very little cross slope exists, the corrugations may be used as directional guides. Where slopes are in excess of 1% and where a cross slope exists, corrugations are operated similarly to furrows in that the water is turned into the corrugate at the upper end and kept confined to the channel. Down-field slopes of up to 5% can be effectively irrigated in this manner.

Both furrows and corrugations are best suited to the finer-textured soil types, since a longer length or run can be used. They are especially suitable for soils that are subject to surface crusting because only a portion of the ground surface is flooded.

The flow diverted into the channel is governed by the capacity of channel, infiltration rate of soil and length of run. Usually, the initial flow rate would be close to the nonerosive stream size to obtain the

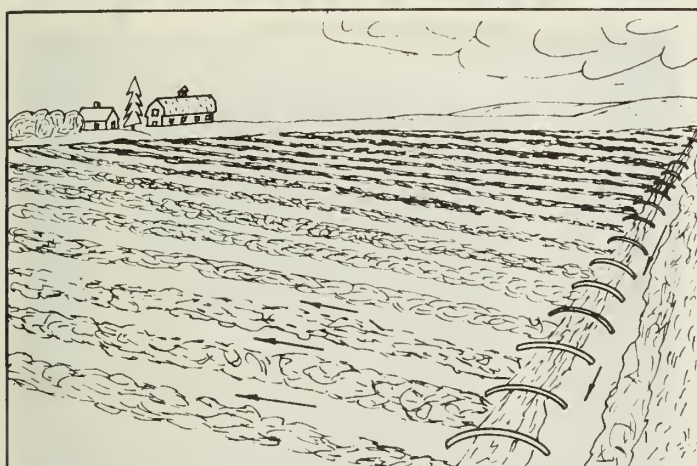


Figure 4. Furrow-corrugation method of irrigation.

maximum length of run. This can be estimated by dividing 10 by the slope in percentage (that is, a 2% slope usually will allow a flow of 5 gpm). The maximum length of run can only be determined by field trial or by comparison with existing systems in the surrounding area. Losses are from both deep percolation and surface runoff. Runoff, deep percolation and a more uniform application can be somewhat controlled by having the water reach the end of the strip in about 20% of the required irrigation time and then cutting back the stream flow. This need for regulation of stream size complicates irrigation. A compromise between runoff and deep percolation can be made and a relatively high efficiency still maintained. It has been found that if the irrigation stream reaches the end of the furrow at between 20 and 50% of the total irrigation application time for loam soils, a satisfactory irrigation application efficiency will have been obtained. Some deep percolation losses will occur, but they should not be excessive, particularly on fine-textured soils.

Generally speaking, these methods can be used on most crops and are particularly suitable for row crops.

Labor costs are generally higher than for border dyke and irrigation time is somewhat slower, depending to a large extent on the capital expended in providing the water supply to the channels. Total costs usually are about the same as for border dyke development and, if field topography is suitable for border dykes, it is recommended that they be used rather than furrows or corrugations. However, it is not uncommon to use both methods. For example, land could be graded to border dyke standards and either corrugations or border dykes used for various crops in rotation.

Land grading requirements for furrows or corrugations are usually substantially less than for border dykes. If the irrigation water is to be retained in the channels, then a considerable cross slope can be tolerated. However, care must be taken to ensure a continuous down-field slope. Debris and sudden changes in slope can cause operation problems. Soil eroded from a steep portion of the field may be deposited where the slope flattens out, causing the channel to be blocked and water to overflow. Supplying water to the furrows can be accomplished by a ditch with small spiles or siphons, or by a gated pipeline operating under either gravity or pump pressure.

Corrugations can be used in conjunction with border dykes. The corrugations help to spread the water over the full width of the strip and may provide a more uniform application of water, particularly for the first irrigation after seeding when the ground is bare.

Basin

This method is based on the rapid application of irrigation water to a level or nearly level area enclosed by dykes. The desired amount of water is turned into the basin and is retained by the dykes until infiltrated into the soil. The method has a high application efficiency, particularly when used on soils with a low intake rate. Maintenance of a level surface is essential to retain this high application efficiency. Where the surface topography is not basically level in its natural state, land-grading costs can be excessive. Surface drainage to remove excess irrigation water or rainfall must be included in the design plans.

Trickle

Trickle or drip irrigation is a new method developed in Israel, in which the entire field is irrigated at once on a continuous or near continuous flow basis. The water is applied to the ground surface near the plants by low-flow (1 gallon per hour or less) drippers or tricklers fed by small-diameter (1/2 or 3/4-inch) plastic pipe, also on the surface. The spacing of this network of pipe in

the field depends on the crop to be irrigated. The trickle method (12) is being assessed at the Research Station, Summerland, B.C., because of its advantages in irrigating orchards and vineyards. The surface pipe presents no obstruction in a permanent tree or grape row and, because of tree and row spacings, fewer drippers are required per acre. As the soil surface is not wet between the rows and plants are not wetted as they are when sprinkling, operations such as thinning and spraying can be carried out with no need to interrupt the irrigation schedule. This method is not considered practical for irrigation on the prairies.

Automation of Surface Irrigation

Automation of surface irrigation refers to the use of mechanical structures that automatically divert water to the field in the proper amount and at the proper time. The border dyke method is particularly well suited to automation, but the furrow method is more difficult to automate because of the problem of obtaining uniform water distribution for all furrows.

Surface irrigation can be either semiautomatic as developed by Humpherys (4) or fully automatic as developed by Haise, Kruse and Dimick (2). There is, therefore, quite a choice in sophistication of system. Because of cost, and since the operator usually finds himself around the field anyway, the semiautomatic system as developed by Humpherys (4) will be described as it applies to border dyke irrigation.

Two types of permanently located checks that use the timer are the drop and apron gates, commonly made of galvanized iron and mounted in a cutoff wall. The drop gate (Figure 5) is hinged on the top and is normally open. The apron gate (Figure 6) is hinged at the bottom and is normally closed. Before each irrigation the trip mechanism is set so that the drop gate is open and the



Figure 5. Drop gate (normally open, semiautomatic gate).



Figure 6. Apron gate (normally closed, semiautomatic gate).

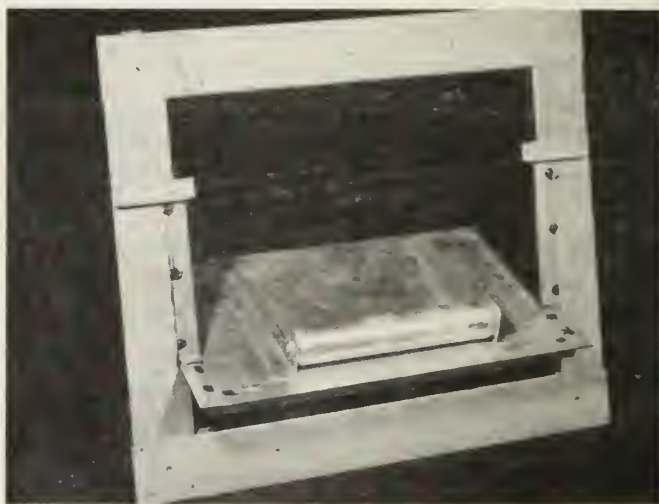


Figure 7. Center-of-pressure gate.

apron gate is closed, and the timer is set for the length of irrigation desired. When the water reaches the structure the float is raised and the clock is started. At the end of the predetermined time the drop gate closes and the apron gate opens. A fully automatic structure is the center-of-pressure gate (Figure 7), which opens when the water reaches a certain height in the ditch and closes when the water level drops.

These gates are used in combination to turn water on and off different sections of the field. One combination in border dyke irrigation is to place the center-of-pressure gate in the head ditch and the drop gate in the turnout (Figure 8). The water is checked by the first pressure gate and flows through the normally open drop gate on the first border strip. At the end of the preset time the timer trips the mechanism, the gate closes, raising the water level sufficiently to open the pressure gate, and the water flows on to the second set. Another arrangement for this same pair of structures is to place the drop gate in the head ditch and the center-of-

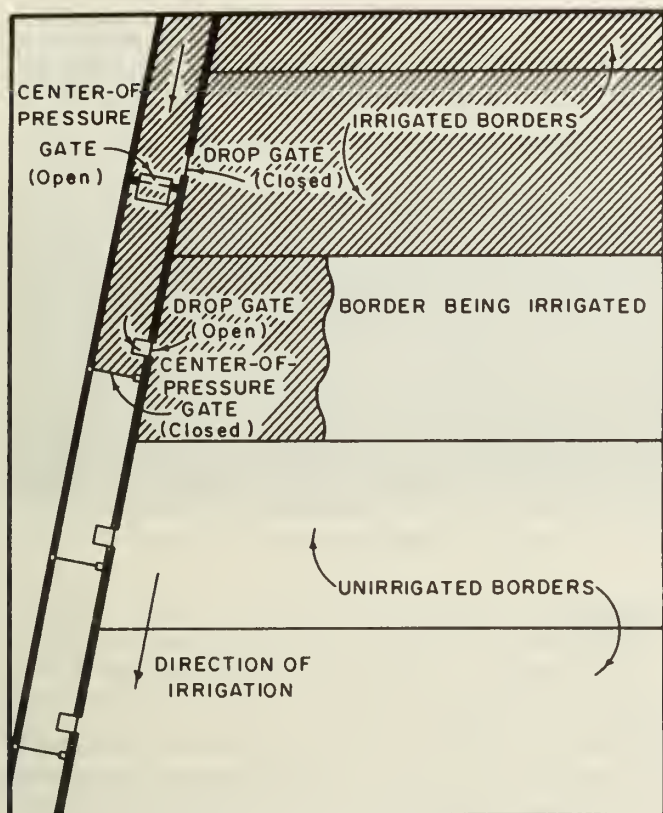


Figure 8. Schematic drawing, Humpherys (4), of automated irrigation using center-of-pressure gate in head ditch and drop gate as a turnout. Direction of irrigation is from upstream to downstream of head ditch and grade of head ditch is minimal.

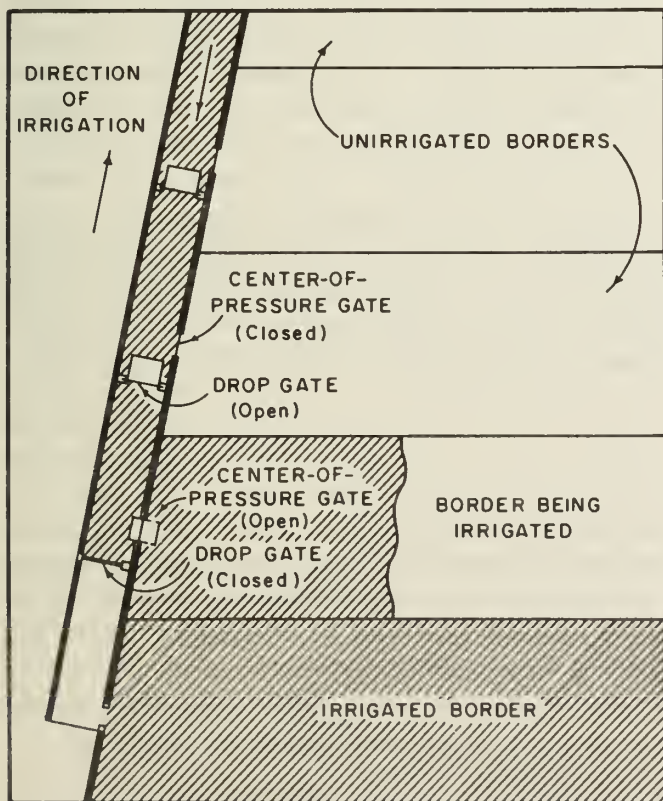


Figure 9. Schematic drawing, Humpherys (4), of automated irrigation using drop gate in head ditch and center-of-pressure gate as turnout. Direction of irrigation is from downstream to upstream of head ditch.

pressure gate in the turnout (Figure 9). If this arrangement is used, the strip at the downstream end of the head ditch is irrigated first and irrigation proceeds toward the upper end of the head ditch. The water in the ditch is checked at the end of the ditch and the level rises until the pressure gate opens. At the end of the preset time the drop gate immediately upstream closes and the pressure gate immediately above it opens and the second strip is irrigated. Figure 10 shows an arrangement using the apron gate and center-of-pressure gate, which is particularly suited to head ditches with considerable slope.

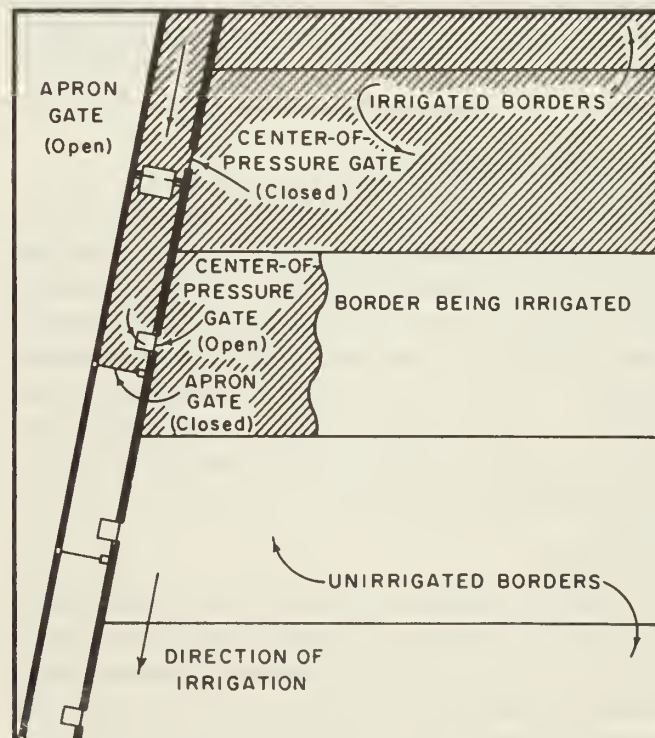


Figure 10. Schematic drawing of automated irrigation, using apron gate in head ditch and center-of-pressure gate as a turnout.

Structure costs fabricated at the Research Station, Swift Current, were as follows: the drop and apron gates cost \$105 each — \$39 for the timer, \$33 for material (16-gauge galvanized iron) and \$33 for labor. The center-of-pressure gate cost \$52 — \$8 for material and \$44 for labor.

Subsurface Irrigation

A very recent innovation is the sophisticated, expensive, subsurface method of irrigation using small diameter plastic pipe with small openings (1, 8). There are several techniques, but the common one is to space the drippers about 1 foot apart in $\frac{1}{2}$ -inch diameter polyethylene pipe and bury the pipelines about 16 inches deep and 4 feet apart. The principle is that the water flow is very slow, a rate equal to that used by the

plant, so the water is fed continuously and directly to the root. The claim is better soil-moisture condition for the plant and no loss from evaporation because the surface soil is not wet. It is very difficult to find any references to cost because the method is in the development stage and installations are small for experimental purposes. The cost is excessive, though, with estimates in the range of \$1500 an acre. Other disadvantages are: the need for very careful screening of the water, plugging of openings, excessive downward movement of water unless soil is fine textured, and possible problems of salinity. It will be very interesting to follow the development of this method of irrigation, but it would appear that it will be limited to greenhouse or highly specialized crops if and when the problems now being encountered are overcome.

Sprinkler Irrigation

The main advantage of sprinkler irrigation is that it can be used on lands that are difficult or impossible to irrigate by surface methods. Other advantages, such as better control in the application of small amounts of water, simplicity or ease of converting from dryland to irrigation farming, and personal preference of the operator, particularly of newer, mechanical-move systems, tend to compensate for the higher cost of sprinkler irrigation.

Hand-Move

Sprinkler irrigation became practical with the introduction of lightweight aluminum pipe and quick couplers in the late 1940s. Hand-move systems are either completely portable or semiportable; in the latter, the pump and main line are permanently located. The main disadvantage of a hand-move is the high labor requirement for moving the pipe.

Giant Sprinklers

A giant sprinkler system consists of one or more large sprinklers discharging from 100 to several hundred gallons a minute over an area of 200 feet or more in diameter.

The disadvantages of giant sprinklers are the high cost of operation caused by the high pressure required to operate the sprinklers, and the high rate of application and poor uniformity of water application under windy conditions. These disadvantages are overcome to some extent by mounting a sprinkler in the form of a multiple-nozzle rotating boom up to 250 feet long on a trailer (Figure 11). These boom sprinklers operate at a lower pressure than ordinary giant sprinklers (80 psi, compared with 150 to 200 psi) and the uniformity of application is better under windy conditions.



Figure 11. General view of boom sprinkler on trailer.

Towline

The towline is a hand-move system equipped with skids or castor-type wheels at each coupler. The sprinkler line (lateral) is end-towed by truck or tractor from one set to the next. These systems are best suited for irrigation of pasture and hay crops where traction is better for the towing vehicle.

Side-Roll

In this system, the lateral is usually $\frac{1}{4}$ mile long mounted on wheels 5 to 6 feet in diameter and spaced 40 feet apart (Figure 12). The lateral is moved from one set to the next by a power unit that rotates the pipe, which serves as the axle. The common power unit is an air-cooled gasoline engine in the center of the lateral. The procedure when moving to the next set is to disconnect the lateral from the main line, walk to the power unit, move the lateral, return to the main line and reconnect. Table 2 compares times required for various steps in moving side-roll and hand-move equipment. The main delay in the side-roll was the time required to drain the lateral. The system was operating on rolling land so that a large part of the water in the lateral had to drain through the few drain valves located in the low spots. The labor required to move from one end of the field to the other to start the next irrigation was about the same for both, the side-roll taking two men 86 minutes and the hand-move four men 40 minutes. A tractor and trailer were required for the hand-move.

The side-roll is very popular because the annual operating cost is about the same as for a hand-move. Its main disadvantage is its limitation to low-growing crops because the pipe is only about 3 feet above the ground.

A modification of the side-roll that has not proved successful is the addition of trailer lines. Each trailer line



Figure 12. General view of side-roll lateral.

TABLE 2. TIME* REQUIRED FOR ONE MAN TO MOVE TWO TYPES OF SPRINKLER LINE A DISTANCE OF 60 FEET

Elapsed time to	Side-roll	Hand-move
Disconnect and connect hand-move lateral		3
Disconnect side-roll lateral	3	
Drain side-roll lateral	25	
Walk to power unit in center of side-roll lateral	3	
Move lateral 60 feet	3	60
Walk back to main line	3	7
Connect side-roll lateral	2	
Total	39	70

*Minutes.

has up to three sprinklers, which means that each set is equivalent to four laterals, or four moves. The objective is to reduce labor but the problem of the trailer line catching in the crop and tipping over, as well as mechanical problems, tends to outweigh any advantage in labor saving.

Center-Pivot

In this system the water supply is delivered to the center of a quarter section and the lateral, again usually 1/4 mile long, is self-propelled in a circle around the central pivot point (Figure 13). The lateral is supported on two-wheeled or tracked towers usually spaced 96 feet apart. There are four methods of powering the system:

- Hydraulic water drive — piston type,
— sprinkler type;
- Hydraulic oil drive;
- Electrical drive; and
- Air drive.



Figure 13. General view of center-pivot lateral.

The towers along the lateral are kept in position by an alignment system that speeds up a lagging tower or reduces the speed of one that gets ahead. The transport units on the towers can be swung 90° so the lateral can be end-towed to the next quarter section. The use of one center-pivot on two quarter sections is not uncommon on the prairies.

The sprinklers along the lateral are graduated in size so that a constant depth of water is applied along its length. The depth of water applied is adjusted by selecting the length of time required per revolution which can vary from 8 hours (fraction of an inch) to 7 days (several inches). The pressure required at the pivot is about 80 psi and the capacity of the system varies in the range of 750 to 1100 gpm.

The initial cost of a center-pivot used on two quarter sections is about the same as that of two 2-lateral side-rolls (Table 3). Both systems are used to irrigate two quarter sections; but since fewer acres are irrigated (corners missed) by the center-pivot, its cost per acre is higher.

The center-pivot can be used on high crops because the lateral is 7 to 9 feet above the ground. The labor requirement is low (50 hours per irrigation for two quarter sections, compared with 140 hours for the side-roll system).

A disadvantage of the center-pivot is the high rate of application at the outer end, which limits its use to coarse- and medium-textured soils.

'Square-matic'

The most recent development is the 'square-matic', or straight lateral self-propelled continuously moving system, which looks like a side-roll on the move. The developer of this method claims better uniformity at a

lower rate of application and complete coverage of a quarter section, including the corners. The system can travel 1320 feet unattended, at which time it stops automatically, and the operator disconnects, moves and reconnects the 600-foot length of hose. The system travels the 1320 feet in 12 to 48 hours and applies $1\frac{1}{2}$ to 2 inches of water. The average labor requirement for 160 acres is about 6 man-hours.

Traveling Sprinklers

In a traveler system, a giant sprinkler is mounted on a trailer and moved continuously by a winch. The winch is powered by a water turbine, using the flow of water to the sprinkler, or by a small gasoline or bottled gas engine. Most common traveling sprinklers are fed by a flexible hose from a main line. A more completely mechanized sprinkler system has a sprinkler, pump, ditch guidance device, and portable dam all mounted on a four-wheeled, engine-powered unit that straddles the ditch. The sprinkler is usually a part-circle type so that the land-wheeled unit travels on dry ground. Travelers are limited to medium-textured and coarser soils because of their high rate of application.

Solid-Set

There are several types of solid-set sprinklers:

- *Permanent* — a complete network of buried lines and sprinklers permanently fixed. The system usually is valved so that the field is irrigated in zones and the valves may be operated by a time clock.

- *Permanent with portable sprinklers* — a complete network of buried lines, with turf-type hydrants. The system is divided into zones but there are only enough sprinklers to satisfy a zone or two and the sprinklers are moved. When a sprinkler is removed from the hydrant there is no aboveground obstruction such as with the first system.

- *Portable* — similar to the first system except that pipelines are placed on the surface. The usual procedure is to move the system into the field in the spring and pick it up in the fall. The main purpose of portability is to allow the system to move with the crop, say potatoes, as it moves from field to field in the rotation.

- *Sequencing valve ('sequi-matic')* — may have the sprinkler line buried, on the surface, or supported above the crop. The distinguishing feature of this system is the sequencing valve on each sprinkler riser that turns the sprinkler on and off as activated by a controller. Since only one sprinkler per sprinkler line is in operation at a time, the sprinkler lines are small-diameter pipe. In operation, the appearance is the same as, say, a hand-move, but the 'line of sprinklers' is perpendicular to the sprinkler lines. The first set consists of the first sprinkler in each line in operation, the second set of the

second sprinkler in each line and so on.

Because of its high cost, the solid-set system is limited to specialty crops such as orchards and truck crops. It requires very little labor for operation and has the added advantage that it can be used for frost protection.

Comparison of Surface and Sprinkler Irrigation

The main advantage of sprinkler irrigation is its universality. Besides being applicable to conditions suitable for surface irrigation, it can be used where it is either difficult or impractical to irrigate by surface methods. Sprinklers, for example, are ideally suited to coarse-textured soils and undulating topography; and any comparison with surface irrigation under these conditions would be of little, if any, significance. However, on the prairies where the soil and topography generally are suitable for surface irrigation, and shortness of the growing season limits the type and number of crops that can be grown, a critical comparison of the advantages of the two methods is essential, with special consideration being given to costs (Table 4).

When conditions are suitable for surface irrigation, and specialized crops such as vegetable crops and sugar beets form an insignificant portion of the total, some of the commonly listed advantages of sprinkler irrigation decrease in importance:

- Control of small flows and uniformity of application, for light application particularly — of little significance when irrigating alfalfa on medium- to fine-textured soils, where depth of water applied per irrigation may be 4 to 5 inches.

- Saving in water — the difference is negligible, since if the soil type is suitable for surface irrigation, losses are not excessive.

- Better irrigation with small flows — of minor significance on the prairies where most water is supplied by gravity from reservoirs (small flows are usually encountered when pumping from wells).

- Elimination of ditches — not important on the prairies, unless the total distribution is by pipeline, because supply ditches make up only about 3% of the area. Surface irrigation by border dyke eliminates field ditches, which are bothersome because they cut a large field into individual narrow strips and present a major weed problem.

The main disadvantages of sprinkling — high cost and poor uniformity of water application during windy periods — are accentuated on the prairies. The short growing season limits the production per acre, and windy periods are a common occurrence. An estimate of irrigation costs on the South Saskatchewan River irrigation project summarizes comparative cost data in the following tables.

TABLE 3. COMPARISON ESTIMATE OF IRRIGATION COSTS

	Border dyke	Side-Roll (2-5" laterals)	Center-Pivot 1- $\frac{1}{4}$ sec.)	Center-Pivot (2- $\frac{1}{4}$ sec.)
Capital cost/acre, \$ ¹	145	155	250	195 ²
Annual cost of capital/acre, \$	13.05	19.25	31.05	24.15
Labor, hr	230	210	50	150
Labor, cost/acre, \$	4.50	4.50	1.10	2.00
Repair, cost/acre, \$	2.50	1.55	3.70	3.95
Power cost (3 irrig.), \$ ³	1.50	7.80	12.00	11.60
Cost/acre/yr, \$	21.55	33.10	47.85	s 41.70

¹ Average capital development costs encountered on the South Saskatchewan River Irrigation Project (S.S.R.I.P.): border dyke, \$145/acre; gravity corrugation, \$120/acre; pump corrugation, \$145/acre; side-roll, \$155/acre; center-pivot serving one $\frac{1}{4}$ section, \$250/acre; center-pivot serving two $\frac{1}{4}$ sections, \$195/acre.

² Center-pivot system moved between two $\frac{1}{4}$ sections. System will physically cover 266 acres but is generally only adequate for 221 acres, depending on pumping rate.

³ Pump operation costs. Costs are included for border dyke but, depending on source of water, may not be required.

TABLE 4. ESTIMATED MEDIAN COST PER ACRE OF GROWING CEREALS, OILSEEDS AND SIMILAR CASH CROPS UNDER VARIOUS CONDITIONS¹

	Surface		Sprinkler	
	Very favorable conditions	Very unfavorable conditions	Very favorable conditions	High cost installation
Development cost				
Land leveling	\$60	\$145	\$ 0	\$ 10
Planning, etc.	10	20	0	0
Crop loss due to leveling	20	40	0	0
Sprinkler			155	250
	90	205	155	260
Annual costs				
Development fixed cost ²	8.10	18.00	19.25	32.30
Buildings fixed cost ³	2.00	2.00	2.00	2.00
Machinery fixed cost	10.50	13.75	9.50	10.50
Machinery operating cost	7.00	9.50	6.50	7.00
Sprinkler operating cost			7.80	12.00
Labor — irrigating	4.00	8.00	4.00	2-6.00
— other	12.00	15.00	11.00	12.00
Other cash costs ³	15.00	15.00	15.00	15.00
Reduced net return on dryland portion ⁴		3.00		
Return to bare land ³	5.00	5.00	5.00	5.00
Subtotal	\$63.40	\$ 89.25	\$ 80.05	\$ 97.80 — 101.80

¹ From an unpublished report *Costs and Returns on Seven Irrigated Farms in the S.S.R.I.P., 1968* (S.S.R.I.P. — South Saskatchewan River Irrigation Project), Saskatchewan Department of Agriculture, Economics and Statistics Branch.

² Sprinklers assumed to have life of 15 years. Interest at 9%. Land leveling assumed to retain value indefinitely. If leveling was written off in 30 years this would add \$0.80 and \$1.50 to columns 1 and 2, respectively.

³ These items could vary considerably but are not dependent on type of irrigation.

⁴ Assuming dryland is cut up into small irregular fields.

The cost of getting water on the land will generally be lower by surface than by sprinkler, but tillage and labor costs will be higher. When we look at total costs, there is a considerable overlap between the two methods. This means that for some parcels total costs will be considerably lower for surface irrigation, on others sprinkler will be cheaper, and on quite a few there will be little difference.

The quality of irrigation water on the prairies is very good because usually the supply is surface water from melting snow. The soils, however, generally have a tendency to be saline. Hobbs and Russel (3) studied the effect of the two methods on the change in soil salinity with time and concluded that the land under sprinkling increased in salinity because there was no leaching.

Sometimes sprinklers have either beneficial or deleterious effects on plants. Cases of increased mildew in beans on the one hand, and increased yields of some of the tender vegetable crops on the other, have been reported when irrigating by sprinkler. At Lethbridge, Krogman and Torfason (7), in a study of the effect of method of irrigation on yield and quality of vegetable crops, concluded "that method of irrigation does not appreciably affect yields or quality of tomatoes, potatoes, and peas provided that the soil is supplied with sufficient water at the right time."

Therefore, the general recommendation on the prairies is to irrigate by surface methods if topography and soil texture are favorable. Sprinklers are indicated for certain high-return crops with special water requirements and where topography and soil texture are unfavorable to surface irrigation.

SURFACE DRAINAGE

Drainage must be considered in the design and planning stages of all irrigation projects, particularly when using surface methods. The objective is to drain off excess irrigation water at the low end of the field. Preliminary land leveling for surface methods of irrigation removes any low spots that may flood, so that excess water can reach the drain. Land leveling is seldom necessary for sprinkler irrigation. However, spots should be eliminated to prevent flooded areas, which hamper movement of sprinklers, particularly mechanical-move types and, of course, cause losses in crop production. Drainage and land grading together eliminate flooded areas, improve or prevent saline soil conditions, and guard against development of waterlogged lands or a high water table. The drainage system, therefore, is nearly as vital as the water supply system in the

development of permanent irrigation facilities for high-production agriculture.

STRUCTURES AND EQUIPMENT

Surface Irrigation Structures and Equipment

Technical accuracy in design, construction and installation of irrigation structures is essential in the development and management of an irrigation project. Fortunately, most of this is looked after by agencies such as PFRA of the federal government, and provincial departments of agriculture. Nearly all of the structures are now made of prefabricated concrete panels. It might be a good idea for individual growers to consider this type of structure in case there is a need for a relatively large check or drop structure.

Checks and Takeouts

A farmer's main concern in irrigation structures for the surface method is a portable dam; or a small permanent check and takeout, such as the recently developed lightweight, prefabricated metal structure shown in Figure 14. The structure illustrated costs about twice the common lumber structure, but should have a very long life. Takeouts and checks can also be made from plywood, preferably treated with a wood preservative by the pressure treatment method (Figure 15).

The installation of certain structures, particularly drops or drop checks in head ditches and main canals, causes certain hydraulic problems. Briefly, these problems center around an increase in velocity of the water passing through the structure and the subsequent dissipation of the accompanying energy.

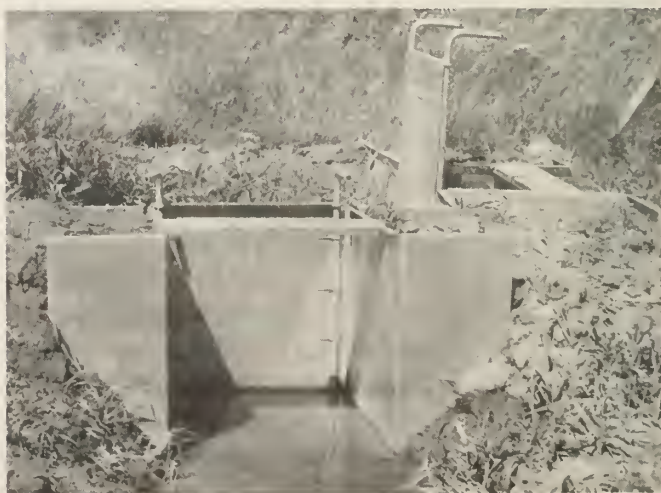


Figure 14. Prefabricated galvanized iron irrigation structure.

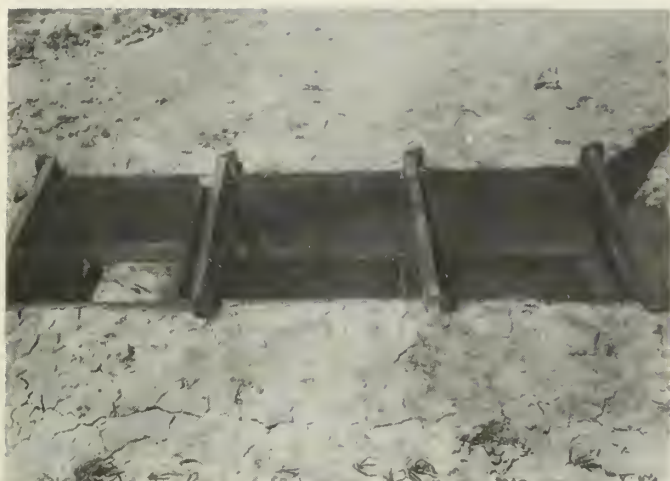


Figure 15. Irrigation structure made of 1-inch pressure creosoted plywood.

The available head — that is difference in water elevation upstream and downstream from the drop structure (Figure 16) — produces an increase in velocity of the water passing through the structure. This increased velocity is associated with a drawdown of the water level, since the cross-sectional area of water flow to pass the same quantity of water will be reduced. The increased velocity leads to scouring of the ditch bottom and sides immediately upstream of the structure, and produces erosion downstream of the structure. Unless this scouring and turbulence can be confined or reduced, the structure may be washed out.

A solution to this problem developed by the Conservation and Land Improvement Branch (formerly Conservation and Development Branch) of the Saskatchewan Department of Agriculture* is to incorporate an elevated crest in the structure design. The elevated crest performs two functions: The reduction of the available weir head (Figure 17) reduces the velocity and, therefore, the drawdown; and it also changes the ratio of head to height of drop, alleviating the problem of downstream erosion through a reduction in the distance "X". Improvement of drop structure operation by means of the elevated crest is detailed in plans No. S.P. 164G and S.P. 164H, available from the Conservation and Land Improvement Branch, Saskatchewan Department of Agriculture, Administration Building, Regina, Saskatchewan.

*Unpublished report — Hydraulic Model Study for Precast Concrete Vertical Drop Structures, prepared by C.D. Smith for Conservation and Development Branch, Saskatchewan Department of Agriculture, Regina, Saskatchewan, August 1966.

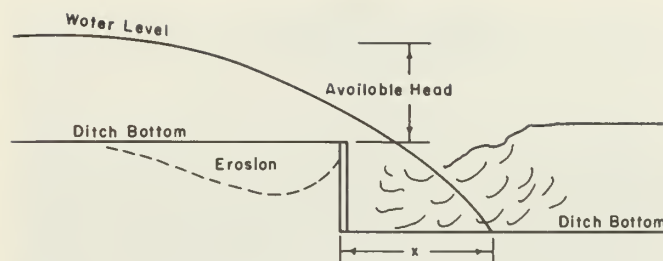


Figure 16. Schematic drawing showing problems of drawdown and erosion above and below irrigation structure.

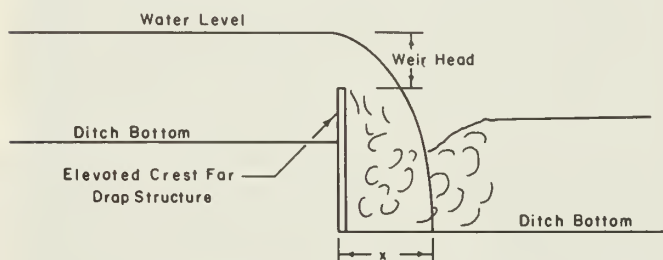


Figure 17. Schematic drawing showing use of elevated crest to overcome erosion problems.

Takeouts —

- Vitrified clay pipe is popular because it is readily available in the size usually required (8 inches in diameter, at about \$4 per tile), and is not damaged if ditches are cleaned by burning. This pipe is heavy, however, making it difficult to install, and the common length is somewhat short for many installations. The pipe is closed simply by placing a sheet of $\frac{1}{4}$ -inch plywood over the opening. The outlet invert of the tile should be below the field elevation of the border strip.

- Galvanized steel with gate provides a positive water shutoff, is relatively easy to install and is not damaged by fire. The main disadvantage is its relatively high cost of \$10 to \$15.

- Plywood is relatively cheap, light and easy to handle, but is difficult to install and will burn.

- A spile is a very small takeout to distribute the flow to an individual furrow. Spiles can be made by nailing four laths together, or by cutting 1- or $1\frac{1}{2}$ -inch pipe into suitable lengths. The spiles are dug into the irrigation ditch bank so that they are at about the same level as the bottom of the furrow.

Siphons

Siphons (Figure 18) can be used instead of a takeout or gate to divert water from the supply ditch to the strip in border dyke irrigation, or instead of spiles to distribute water to individual furrows. Siphons can be made from aluminum, plastic or rubber, but aluminum siphons are the most common. The water flow is

regulated mostly by the size and number of units used, but it can be adjusted slightly by raising or lowering the outlet end of the siphon. These adjustments are easier to make, and siphons are easier to start, when the supply ditch is placed on a pad so that ample head is available. Siphons have not been generally accepted because of the additional expense of raising the ditch, the labor required to start the siphons, and the obvious problems that occur when siphons lose their prime.

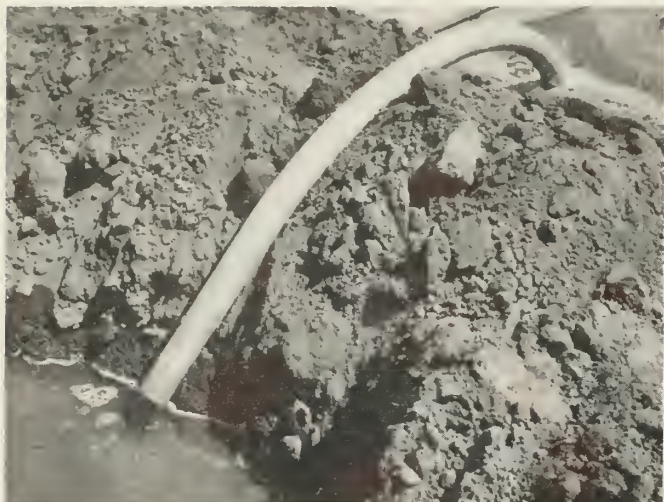


Figure 18. Irrigating by siphon.

Gated Pipe

Gated pipe (Figure 19) is a system of conveyance and distribution. The pipe replaces the supply ditch and the water is distributed to individual furrows through adjustable gates in the pipe. The gates can be placed at any spacing desired and are usually spaced to fit the row spacing. A fine degree of control is available, as the gates are very easy to adjust.

The system requires only a few feet of head to operate and this can quite often be obtained by gravity. However, if a pump is required, the cost for power is considerably less than when sprinkling because the pressure requirement is minimal. Gated-pipe should be given serious consideration as an alternative to sprinkling on irregular land that is too costly to prepare for the border dyke method.

Land Leveling Equipment

Land leveling and the broader aspect of land preparation are described in the Canada Department of Agriculture publication 1145, *The Engineering Aspects of Land Leveling* (10), so they are not discussed in detail here. Most of the leveling is usually contracted out. The farmers' main concern is the planing or smoothing operation, a very important part of land preparation that



Figure 19. Irrigation by gated pipe.

should be done before each crop seeding. The smoothing operation removes any irregularities that have developed, such as dead furrows and tractor tracks. The removal of these irregularities facilitates irrigation, particularly the first irrigation before the crop has become established.

Land planes are recommended for the smoothing operation. These come in a variety of sizes (length and width), but essentially all that has to be considered is to get as long a machine as economically feasible. Before the dykes are installed the planing operation should be done in two or three passes, traveling at a different angle for each successive pass; the first two passes could be diagonal passes and the final one across the slope. In subsequent years, when the dykes are in, there is really no alternative but to travel up and down the slope between the dykes; passes should be overlapped by at least 50%.

The planing job can be facilitated by paying particular attention to all field operations. For example, a rototiller does not throw dirt sideways as a plow does; and tractor tracks will be less accentuated if field operations are conducted under correct soil moisture conditions. Watch the speed of travel and adjustment of the equipment; a change in depth of tillage from one part of the field to another will produce irregularities on the surface.

Equipment for Construction of Dykes

Dykes cannot be put in until the final land leveling operation has been completed. However, dyke construction will disturb the leveled surface, unless dirt is hauled in, which is impractical. Use of an A-crowder (Figure 20) or disk (Figure 21) produces a dyke by borrowing dirt adjacent to the dyke. This leaves the center strip high with a low area at the sides of the strip. A machine,



Figure 20. Constructing a dyke with A-crowder.



Figure 21. Constructing a dyke with double-gang disk.

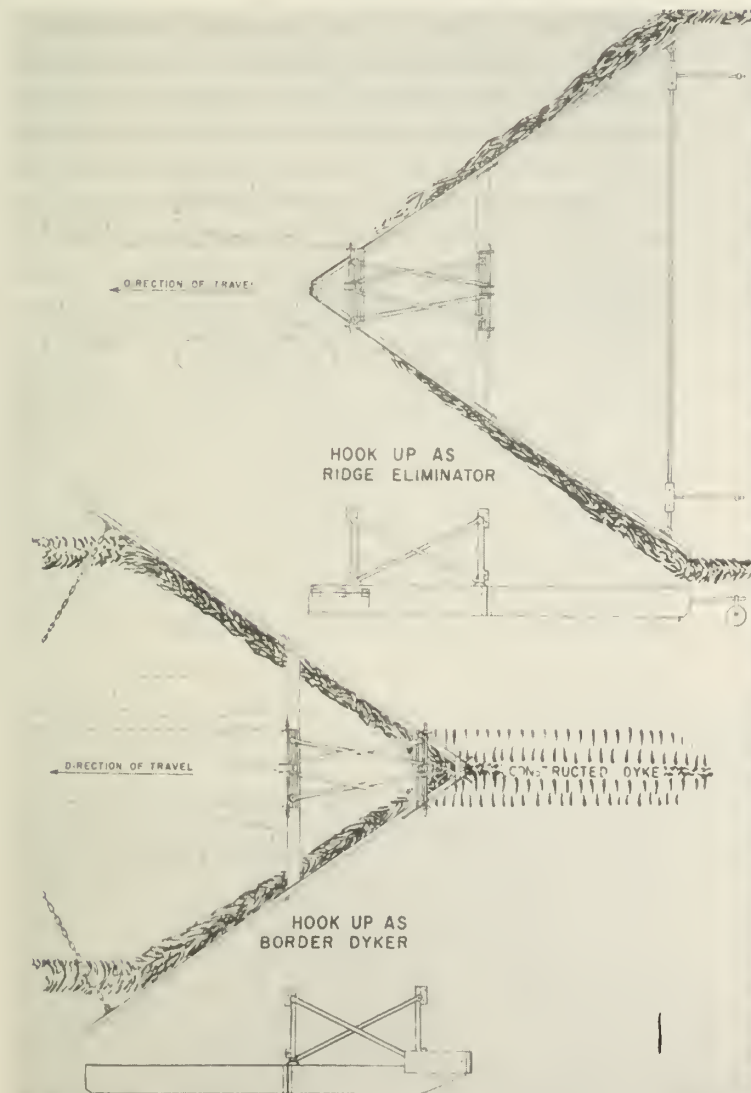
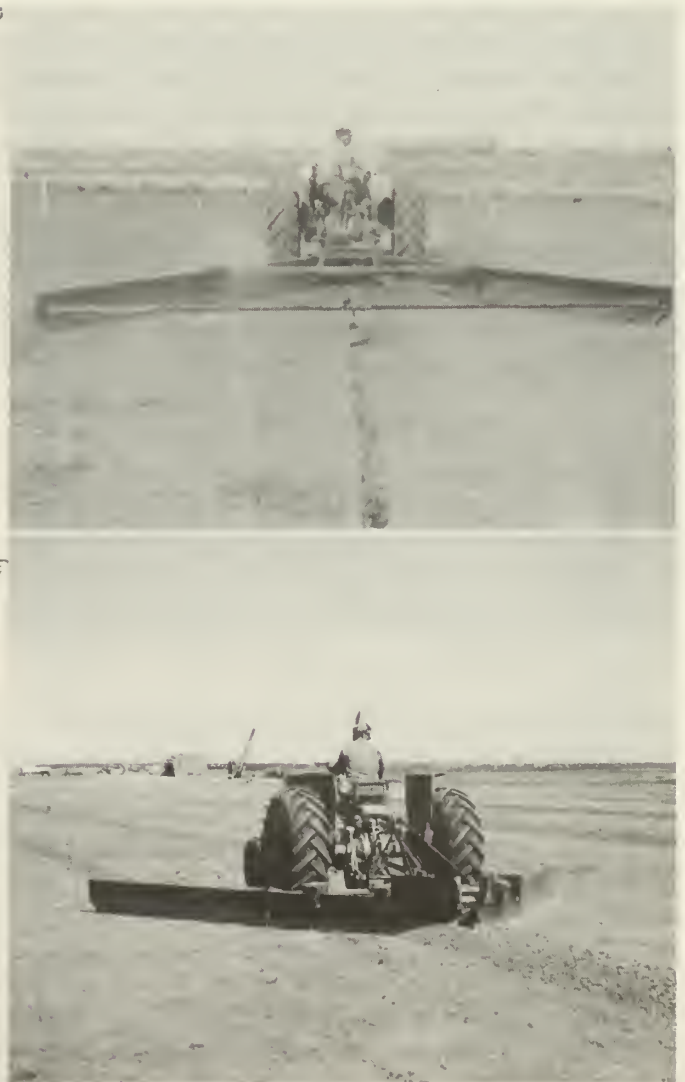


Figure 22. Constructing a dyke with dyking master.

known as the "dyking master" (Figure 22) has been developed that overcomes the problems associated with the use of the A-crowder. This machine is a modification of the A-crowder, and the dirt for the dyke is obtained by scraping the full width of the strip. Plans and operat-



ing instructions may be obtained from the Water Resources Division, Alberta Department of Environment, Lethbridge, Alberta. Dykes can also be constructed by use of a blade machine (motor grader), preferably with a leveling device and again scraping the full width of the strip.

Equipment for Construction of Furrows and Corrugations

Corrugations or furrows are usually made after the crop has been seeded. The furrows can be pressed in by dragging 2 $\frac{1}{2}$ - to 4-foot sections of 8- to 20-inch pipe over the surface of the ground. The ground surface has to be soft for this procedure to be satisfactory, and it may be necessary to bevel the leading end of the pipe sections so that they do not dig in. On firmer ground, it is necessary to dig out the furrows using cultivator-type shovels and shapers attached to a three-point hitch (Figure 23). These corrugators simply push the soil up and out of the furrow, leaving a bank along both sides so that the field surface becomes quite rough. Under certain soil conditions, and in land seeded to grass, this type of corrugator may not perform satisfactorily. Then it may be necessary to use a larger, heavier corrugating machine (Figure 24) that digs the soil out of the furrow by means of rotary cutters and spreads it out between



Figure 23. Drag-type five-row corrugator.

the furrows. This machine handles tight, fine-textured soils and leaves a much smoother field for farming operations, which is a definite consideration in close-growing crops.

Irrigation Ditch Maintenance

Most irrigators have experienced the frustration of irrigating with a reduced flow of water caused by weeds and grass in the head ditch.

Mechanical cleaning by stripping off the vegetation with a ditcher is relatively simple, but not acceptable because after several passes the ditch becomes too large. At this point the cost becomes a factor because of the necessary rebuilding program.

Burning in the fall does not cost much, but is effective only for the first irrigation in the next season. Burning the green material can be achieved by using a propane or other type of burner. However, this procedure has not been generally accepted, because of the time required to provide two burnings per season at a cost of \$40 to \$50 per mile of ditch per year.

The use of chemicals, particularly sterilants, is being studied because of the possibility of control over several years. The procedure in the study was to apply the sterilants in the fall, and to pond and drain away the first water the following spring. The study to date has shown that sterilants are effective for a period of 3 to 4 years at an annual cost of \$50 to \$75 per acre. When the first water in the spring following application was ponded and drained away, little, if any, field damage was noted. However, sometimes when the water broke out of the ditch into the field during spring runoff, the



Figure 24. Cutter-type five-row corrugating machine.



chemical did some damage to the crop. Another problem was damage to the ditch from erosion in coarse-textured soils. Sterilants, therefore, cannot be recommended at this time. The study is continuing to monitor movement of the sterilants, to assess other chemicals, such as contact chemicals, and to evaluate other methods of growth control such as mowing, burning and seeding low-growing grasses in the ditches.

The contact chemicals show promise after the third annual application (June), as does seeding the ditch to streambank wheatgrass, Russian wild ryegrass or sheep fescue.

The Pump

A pump is required when the water level is lower than the level of land to be irrigated or when the sprinkler irrigation method has been selected. There is a variety of pumps available with the most common being the centrifugal pump.

Centrifugal Pump

The centrifugal pump is used because of its simplicity and its capability to handle a wide range of operating conditions. Centrifugal pumps are built on either a horizontal or vertical shaft. The vertical centrifugal pump may operate with the impeller submerged or at a point above the water surface, whereas the horizontal centrifugal operates only above the water surface. For either pump, when set above the water level, the suction pipe must be filled (primed) and all the air expelled. The horizontal centrifugal pump (Figure 25) is the more popular because it is easier to install, is mobile and is more accessible for inspection and maintenance. Since these pumps deliver flows at moderate to high pressures, they are particularly suitable for sprinkler irrigation.



Figure 25. Horizontal centrifugal pump.

Propeller Pump

The propeller pump is adapted to delivering a large quantity of water at low heads (Figure 26). It delivers more water than the centrifugal pump for the same size impeller, and is particularly suited to surface irrigation methods and drainage. There are two types of propeller pumps, the axial flow and the mixed flow. The axial flow pump provides an upward thrust to the water and centrifugal action plays no part. The impeller is similar to that of a boat propeller. Low heads of about 10 to 12 feet are usual with this type. The mixed flow pump provides moderate heads of around 20 to 40 feet. This type is similar to the axial but has curved propeller blades, and thus combines the axial and centrifugal principles in building up pressure. These pumps are not suited for suction lift so the impeller must be submerged. Care must be taken to follow manufacturers' recommendations on the amount of submergence and clearance between the bottom and walls of the intake sump.

All pumps may be single stage or multistage. With the latter, two or more impellers are arranged in series. The quantity of flow is the same as for one alone, but the total head developed by the unit is the product of the head of one stage times the number of stages. The deep well turbine pump is a specific pump adapted for use in deep-cased wells. The pump diameter is small, limited in size by the well casing, and generally several stages are used. Deep well turbine pumps can be used where the water surface is several hundred feet below ground.



Figure 26. Vertical centrifugal pump (high volume, low head).

Selection of Pump and Power Unit

Care must be taken in selecting a pumping unit, to ensure that it will provide the performance required. The type of pump to use depends on the design of the whole

system and several factors must be considered, the main points being:

- Type of water supply and quantity available.
- Vertical suction lift — difference in elevation from low water level to pump.
- Length and size of suction line required.
- Vertical pressure lift — difference in elevation from pump to high point of discharge line.
- Length and size of discharge line required.
- Valves and other accessories.
- Method of irrigation.
- Acreage to be irrigated and dimensions of the field.
- Type of soil.
- Power available.

The recommended procedure, therefore, when purchasing a pump is to supply the dealer with pertinent information so that the pump selected meets the specific requirements. It is further recommended that the pump and power unit be purchased as a package to ensure that the two components are matched in terms of power and speed.

The power requirements can be calculated from the formula:

$$\text{BHP} = \frac{\text{U.S. gpm} \times \text{head (in feet)}}{3960 \times \text{efficiency}}$$

to determine if an available power unit is suitable. The availability of such a power unit and its specifications should be known during the design stage, because the sizing of the pipelines can sometimes be matched to the power unit. The term "head" is pressure expressed in feet; it includes the static lift (difference in elevation from water level to high point of discharge), the friction loss in pipe and fittings, and the pressure required at the point of discharge. Each centrifugal pump can deliver a wide range of discharge and pressure combinations, but there is a point of maximum efficiency or a relatively narrow range of optimum efficiencies. The maximum efficiency, and the range available in flows and pressure available at the optimum efficiency, depends on the characteristics of the pump. This information is available in the form of pump characteristic curves. The pump distributor, with the aid of characteristic curves, selects a pump that will meet the design requirements at maximum of optimum efficiency and then calculates the power requirement.

Power units must be selected that will deliver adequate power under all conditions likely to be encountered. Electric motors are rated at 100% continuous operation and thus the calculated horsepower required is the motor size required. However, for

internal combustion engines, consideration must be given to the engine performance curves. Generally, manufacturers prepare a graph with three curves depicting the maximum horsepower, intermittent horsepower and continuous horsepower for various engine speeds. The continuous horsepower curve is the rating required for pump operation and this curve will have values as much as 20% less than those on the maximum curve. The continuous horsepower curve may require further adjustments for temperature, elevation and accessories.

Pump Operating Hints

If pump fails to prime when priming by adding water to pump:

- Foot valve may be leaking.
- Part of suction line may be higher than pump, so that an air block is formed in suction line.
- Air may be trapped in suction line if it has to escape by same opening through which water is being added. A good procedure is to add water through an opening in discharge pipe above pump and allow air to escape through opening at top of pump casing.

If pump fails to prime when priming by exhausting air, either by an exhaust primer or a vacuum-type pump:

- Check valve on discharge side of pump may not be closed.

If pump stops pumping, air may have entered the system because:

- There may be a leak in suction line or pump drain plug.
- Pump packing may be leaking excessively. Adjust pump packing nuts so that leakage is at a rate of only a few drops per minute.
- End of suction line may be insufficiently submerged so that a vortex forms, allowing air to enter.

If pressure or discharge is lower than usual:

- Pump speed may be below normal. Check speed of power unit and check for belt slippage if not direct-drive type.
- Strainer or suction line may be partly blocked.
- End of suction line may be insufficiently submerged.
- Total dynamic suction head may be excessive. Allowable limit is about 20 feet; if pump is 15 feet above the water there are only 5 feet left for friction loss in suction line and fittings and this can be used up in a suction line of 35 to 40 feet. For best operation, pump should be placed as close to water surface as possible.
- Impeller may be partly plugged.

TABLE 5. CAPITAL AND ANNUAL COSTS OF OPERATION FOR CENTRIFUGAL PUMPS

Power	Useful life	Horse-power	Hours per season	Capital	Cost \$ Annual \$/yr ¹		
					Fixed ²	Seasonal ³	Total
Diesel	engine, 12– 14 yr pump, 15 yr	25	500	3800	530	310	840
			800			470	1000
			1000			570	1100
			1200			680	1210
			1400			790	1320
		50	500	4400	610	570	1180
			800			890	1500
			1000			1100	1710
			1200			1310	1920
			1400			1520	2130
		100	500	6600	920	1100	2020
			800			1720	2640
			1000			2150	3070
			1200			2570	3490
			1400			2990	3910
Electric	motor, 25 yr pump, 15 yr	25	500	4200 ⁴	440	250	690
			800			420	860
			1000			460	900
			1200			500	940
			1400			550	990
		50	500	4800 ⁴	510	620	1130
			800			750	1260
			1000			840	1350
			1200			930	1440
			1400			1010	1520
		100	500	6500 ⁴	580	1170	1750
			800			1430	2010
			1000			1600	2180
			1200			1770	2350
			1400			1940	2520
Propane	engine, 10– 12 yr pump, 15 yr	25	500	3700	580	440	1020
			800			680	1260
			1000			840	1420
			1200			990	1570
			1400			1150	1730
		50	500	4200	650	830	1480
			800			1310	1960
			1000			1620	2270
			1200			1940	2590
			1400			2250	2900
		100	500	6000	930	1620	2550
			800			2570	3500
			1000			3200	4130
			1200			3830	4760
			1400			4460	5390

¹ Costs based on experience gained by the Conservation and Land Improvement Branch, Saskatchewan Department of Agriculture.

² Interest at 9%.

³ Seasonal costs: Diesel – 2¢/BHP/hr for fuel, oil, grease and repairs. Fuel @ \$0.31/gal; pump repairs \$50/yr. Electric – (Saskatchewan Power Corporation) schedule of rates plus \$30 for motor repairs plus \$50 for pump repairs. Propane – 3¢/BHP/hr for fuel oil, grease and repairs. Fuel \$0.28/gal; pump repairs \$50/yr.

⁴ Includes S.P.C. capital levy (cost will be dependent however on proximity to 3-phase power source).

If pump takes more power than specified:

- Check pump rpm.
- Total dynamic head (pressure) may be lower than calculated, so that pump is delivering enough additional water to increase the required horsepower.
- Pump and power unit may not be lined up; belt drive may be slipping.

If pump is noisy:

- Suction head may be too large or there may be insufficient submergence causing cavitation of impeller.
- Shaft may be bent, bearings worn, or pump and power unit may not be lined up.

Irrigation Pumping Costs

The need to pump increases the cost of irrigation. Pump operating costs are directly related to horsepower requirements and hours of operation. Pumping costs can be divided into fixed and seasonal charges. Fixed costs are those related to capital expenditures and they therefore exist whether the pump is operated or not. Seasonal costs, on the other hand, vary from year to year depending on how much the pumps are operated.

Table 5 summarizes the comparative operating costs for three sizes of three types of power units over a range of operating times per season. Hours of pumping for surface irrigation usually range from 300 to 500 per season for border dyke and up to 1000 hours for gated-pipe. A pumping operation for sprinkler irrigation would probably vary from 1000 hours to in excess of 1200 hours.

Sprinkler Irrigation Equipment

Operating Hints

The common pipe layout for a sprinkler irrigation system is a main line down the middle of the field with two or four sprinkler lines working from both sides and at right angles to it. Furthermore, the size of the main line pipe in all probability has been selected on the basis that half the sprinkler lines start at each end of the main line and are moved toward the center. This design minimizes the size of the main line required because the total flow does not go past the midpoint. If the arrangement of sprinkler lines is changed so that all the sprinkler lines are moved along the main line together they either start or finish at the end of the line, at which time the friction loss in the main line is the greatest. This reduces the pressure at the sprinklers and the uniformity of water application is impaired. The usual sprinkler spacing for an impact-type sprinkler of field size is 40 X 60 feet.

Studies at Swift Current (5) to measure the uniformity of water application by sprinkler irrigation, with special emphasis on the effect of wind, showed that it was practically impossible to achieve uniformity coefficients of 70% or better when the wind speed exceeded 10 miles an hour. A square spacing of 50 X 50 feet did not improve the uniformity over that obtained at the rectangular spacing of 40 X 60 feet. A marked improvement was not obtained until a spacing of 40 X 40 feet was used, and since this closer spacing increased the cost of irrigating and was beneficial only during periods of wind, the general practice was to continue with the 40 X 60-foot spacing when using an impact-type single- or double-nozzle sprinkler that operated at a pressure of about 45 pounds per square inch.

The recommended spacing for a smaller, garden-type sprinkler — a single-nozzle sprinkler that operated at 25 to 30 pounds per square inch pressure at the sprinkler — was established at 30 X 30 feet on the basis of this study. A low-angle sprinkler of this size (commonly used for irrigating under trees in the Okanagan Valley of British Columbia) and a low-angle field sprinkler were studied, but when compared on the basis of similar spacings the uniformity of water applications was inferior to that obtained by the 'regular' sprinkler.

Care of Sprinkler Equipment

Sprinkler irrigation equipment is not particularly difficult to keep in running order, but it is good business to check over the system and make any necessary repairs before storing it away for the winter.

Inspection and repairs —

- Replace cracked gaskets.
- Remove kinks from pipe, particularly at the ends.
- Replace bent or cracked coupler clamps.
- Check all sprinklers and replace bearing washers that have become worn. Check for any wear in nozzle by inserting drill bits until a snug fit is obtained. If size of bit required exceeds nozzle size stamped on nozzle by 1/64 inch, nozzle should be replaced. Enlarged nozzles can cause one or two undesirable situations; if pump and engine are designed to handle original nozzle size, pressure is reduced and water is not applied as uniformly as when the system was new; and if pump and engine are overdesigned, enlarged nozzles apply more water than planned for originally.
- Rethread riser pipes if threads are damaged. If damaged threads are a common occurrence, make a note to be sure to use aluminum pipe thread compound next year.
- Check pump and engine for needed repairs. If pump has been operating satisfactorily, about the only thing that has to be checked is the pump packing.

Storage —

- Side-roll laterals stored on site should be uncoupled in several locations to protect against contraction, and should be solidly braced between wheels to prevent damage from vibration due to winds. Make certain that laterals are tied down to prevent winds from rolling them away.

- Pipes, couplers and fittings can be stored in the open. It is advisable, however, to stack pipe and fittings off the ground.

- Remove foot valve leather and store in a can of oil.

- Drain pump and leave drain cock open.

- Drain engine crankcase, clean oil filter and air-cleaner, and refill crankcase. Run engine for a short time to allow oil to circulate.

- Drain fuel tank, line and carburetor to prevent gum deposits on valves.

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DEFINITIONS

Consumptive use: Total amount of water required to produce a crop, including amount used by plant (transpiration) and that evaporated from soil surface; also referred to as seasonal water use.

Irrigation requirements: The quantity of water, exclusive of effective precipitation, that is required for crop production.

Water application efficiency: The ratio of depth of water stored in root zone to depth of water applied.

Land gradings: Alteration of existing topography in such a way as to make irrigable by surface methods.

Cross slope: The slope or change in elevation of a field perpendicular to the direction of irrigation. Usually expressed as a percentage.

Downfield slope: The change in elevation of a field in the direction of irrigation. Usually expressed as a negative percentage.

Head ditch: Ditch run across upper end of a field to supply water to the field.

Field drains: A shallow ditch constructed in conjunction with land grading at lower end of field to drain away excess water.

Takeout: A structure installed in bank of a head ditch to transfer water from head ditch to field.

Spile: A small turnout to distribute water to a furrow.

Gated pipe: Portable pipe constructed with a number of small gates along one side so that water may run from pipe into corrugations or furrows.

Static head: Vertical distance from water level to high point of discharge.

Static suction head: Vertical distance from water level to center line of pump.

Static discharge head: Vertical distance from center line of pump to high point of discharge.

Friction loss in pipe: The energy consumed as the result of friction in water as it moves through walls of pipe.

Total dynamic head: The sum of static head, plus friction loss in pipe, plus pressure required at point of discharge.

Total dynamic suction head: The sum of static suction head plus friction loss in suction pipe and fittings.

Total dynamic discharge heads: The sum of static discharge head plus friction loss in discharge pipe and fittings plus pressure required at point of discharge.

GPM: Gallons per minute. (U.S. measure used in text because data in pump and sprinkler literature are expressed in U.S. measurements).

Acre: 43,560 square feet.

Cubic foot: 6.24 gallons Imp.; 7.48 gallons U.S.

Acre-foot: Amount of water required to cover 1 acre 1 foot deep. 43,560 cubic feet; 325,850 gallons U.S.; 270,000 gallons Imp.; 12 acre-inches.

Acre-inch: Amount of water required to cover 1 acre 1 inch deep. 27,154 gallons U.S.; 22,500 gallons Imp.

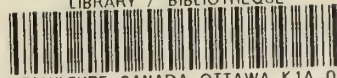
CFS: Cubic feet per second. 7.48 gallons U.S. per second; 6.24 gallons Imp. per second; 450 gallons U.S. per minute; 375 gallons Imp. per minute; approximately 2 acre-feet per day; approximately 1 acre-inch per hour.

CONVERSION FACTORS FOR METRIC SYSTEM

Imperial units	Approximate conversion factor	Results in:
LINEAR		
inch	x 25	millimetre (mm)
foot	x 30	centimetre (cm)
yard	x 0.9	metre (m)
mile	x 1.6	kilometre (km)
AREA		
square inch	x 6.5	square centimetre (cm ²)
square foot	x 0.09	square metre (m ²)
acre	x 0.40	hectare (ha)
VOLUME		
cubic inch	x 16	cubic centimetre (cm ³)
cubic foot	x 28	cubic decimetre (dm ³)
cubic yard	x 0.8	cubic metre (m ³)
fluid ounce	x 28	millilitre (mℓ)
pint	x 0.57	litre (ℓ)
quart	x 1.1	litre (ℓ)
gallon	x 4.5	litre (ℓ)
bushel	x 0.36	hectolitre (hℓ)
WEIGHT		
ounce	x 28	gram (g)
pound	x 0.45	kilogram (kg)
short ton (2000 lb)	x 0.9	tonne (t)
TEMPERATURE		
degree fahrenheit	°F-32 x 0.56 (or °F-32 x 5/9)	degree Celsius (°C)
PRESSURE		
pounds per square inch	x 6.9	kilopascal (kPa)
POWER		
horsepower	x 746	watt (W)
	x 0.75	kilowatt (kW)
SPEED		
feet per second	x 0.30	metres per second (m/s)
miles per hour	x 1.6	kilometres per hour (km/h)
AGRICULTURE		
bushels per acre	x 0.90	hectolitres per hectare (hℓ/ha)
gallons per acre	x 11.23	litres per hectare (ℓ/ha)
quarts per acre	x 2.8	litres per hectare (ℓ/ha)
pints per acre	x 1.4	litres per hectare (ℓ/ha)
fluid ounces per acre	x 70	millilitres per hectare (mℓ/ha)
tons per acre	x 2.24	tonnes per hectare (t/ha)
pounds per acre	x 1.12	kilograms per hectare (kg/ha)
ounces per acre	x 70	grams per hectare (g/ha)
plants per acre	x 2.47	plants per hectare (plants/ha)

Examples: 2 miles x 1.6 = 32 km; 15 bu/ac x 0.90 = 13.5 hℓ/ha

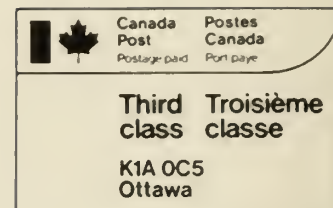
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